TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

No. 102.

SKIN FRICTIONAL RESISTANCE OF PLANE SURFACES IN AIR.

ABSTRACT OF RECENT GERMAN TESTS, WITH NOTES.

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July, 1922.

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SKIN FRICTIONAL RESISTANCE OF PLANE SURFACES IN AIR.

ABSTRACT OF RECENT GERMAN TESTS, WITH NOTES.*

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The most recent research on the skin frictional resistance of plane surfaces in air is that conducted by Dr. Wieselsberger under the direction of Dr. Prandtl of Göttingen University. The results which are given in the "Ergebuisse der Aerodynamischen Versuchanstalt zu Göttingen," for 1921, are of considerable interest and importance. The following abstract has therefore been prepared for the convenience of those who are unable to obtain access to the original.

In all, sixteen models were tested. These were divided into four groups, according to the surface, as follows:

1 - cloth, in the original condition;

2 - cloth, nap singed off;

3 - cloth, three coats of dope;

4 - cloth, six coats of dope.

Each group consisted of four models of uniform width, 1 meter, and of varying length 0.5, 1.0, 1.5, and 2.0 meters. Tests were made on each model at speeds varying from 7.0 to 50 meters per second. The observed total resistance was corrected for the "form resistance" which was obtained from the pressure distribu-

* Originally prepared as Aircraft Technical Note No. 207, Bureau of Aeronautics, Navy Department.

tion on the rear end of the model. Previous tests had shown that the form resistance due to the rounded front edge used on the models was negligible.

The results are expressed in terms of the absolute coefficient of frictional resistance C_F, as defined by the equation

$$R_F = C_F \rho/2 \, SV^2 \qquad (1)$$

where R is the frictional resistance, ρ the air density, S the total frictional area, and V the velocity of the air. (Note: C_F being absolute, this equation is true for any consistent system of units. In the English ft-lb-sec units, V will be in f.p.s., S in ft^2, and ρ in lbs (mass) per ft^3 - the value of ρ corresponding to standard conditions 60°F and 29.92" Hg is $\rho = .00237$.)

It was found for the models of the first two groups that C_F varied erratically when plotted on a logarithmic scale against the Reynolds number VL/ν, where V is the air velocity L the length of the model and ν the kinematic viscosity. This is explained by the variation from true geometric similarity in these models due to the constant roughness. The value of C_F for a given model in either group (1) or (2) does not vary appreciably with (VL/ν), i.e., the frictional resistance varies almost exactly as the square of the velocity when the surface is rough. On the other hand, the values of C_F for the models in groups (3) and (4) decrease quite uniformly with increase in (VL/ν) when plotted logarithmically. In particular, the values of C_F for the models in group (4) (six coats of dope) all lie substantially on a single line whose slope shows that C_F is given by

$$C_F = 0.0375\ (VL/\nu)^{-0.15} \qquad (2)$$

Combining (2) with (1) the complete equation for the skin frictional resistance is

$$R_F = 0.0375\ \rho/2\ B\nu^{0.15}L^{0.85}\ V^{1.85} \qquad (3)$$

where B is the breadth of the single surface. If both sides of the plane be exposed to the air stream the coefficient must be doubled.

As originally presented, the well known empirical formula for skin frictional resistance devised by Dr. Zahm, was

$$R_F = 0.00000778\ BL^{0.93}V^{1.85} \qquad (4)$$

It will be noted that the essential difference between (3) and (4) is in the exponent of L. Equation (4) may be written in the same general form as (3), or

$$R_F = C_F\ \rho\,\nu^{-0.15}\ BL^{0.93}\ \ V^{1.85} \qquad (4a)$$

in which

$$C_F\ \rho/2\,\nu^{-0.15} = 0.00000778 \qquad (5)$$

Substituting the values for standard conditions

$$\rho = .00237, \quad \nu = .0001575 : C_F = 0.0244 \qquad (6)$$

and

$$R_F = 0.0244\ \rho\nu^{0.15}BL^{0.93}V^{1.85} \qquad (4b)$$

Comparing (4b) with (5) it is seen that the difference in the coefficients is partially balanced by the difference in the exponents of L. Equation (3) being dimensionally correct, is preferable, however, to equation (4) which is not dimensionally correct.

The average engineer will prefer to use an equation of the form

$$R_F = C_F \ \rho/2 \ SV^2 \qquad (1)$$

using the value of C_F corrected for the appropriate (VL/ν) according to (2). In order that this may be done without the necessity of looking up data, Figs. 1 and 2 have been prepared. Fig. 1 gives the value of ν corresponding to any ordinary temperature and pressure. VL/ν is therefore known for the given velocity and length. (It is desirable to note that the value of ν in English units (ft^2 - sec) for a temperature of 60°F and a pressure of 29.92" is $\nu_o = 0.0001575$ and $1/\nu_o = 6350$. Therefore, under standard conditions, $VL/\nu = 6350$ VL.) The value of C_F is obtained from Fig. 2, in which C_F is plotted against VL/ν. In comparing C_F with the absolute drag coefficient C_D it is necessary to use the factor 2, since the area in (1) is the surface area, while the area in the equation

$$R = C_D \ \rho/2 \ SV^2 \qquad (7)$$

is the projected area.

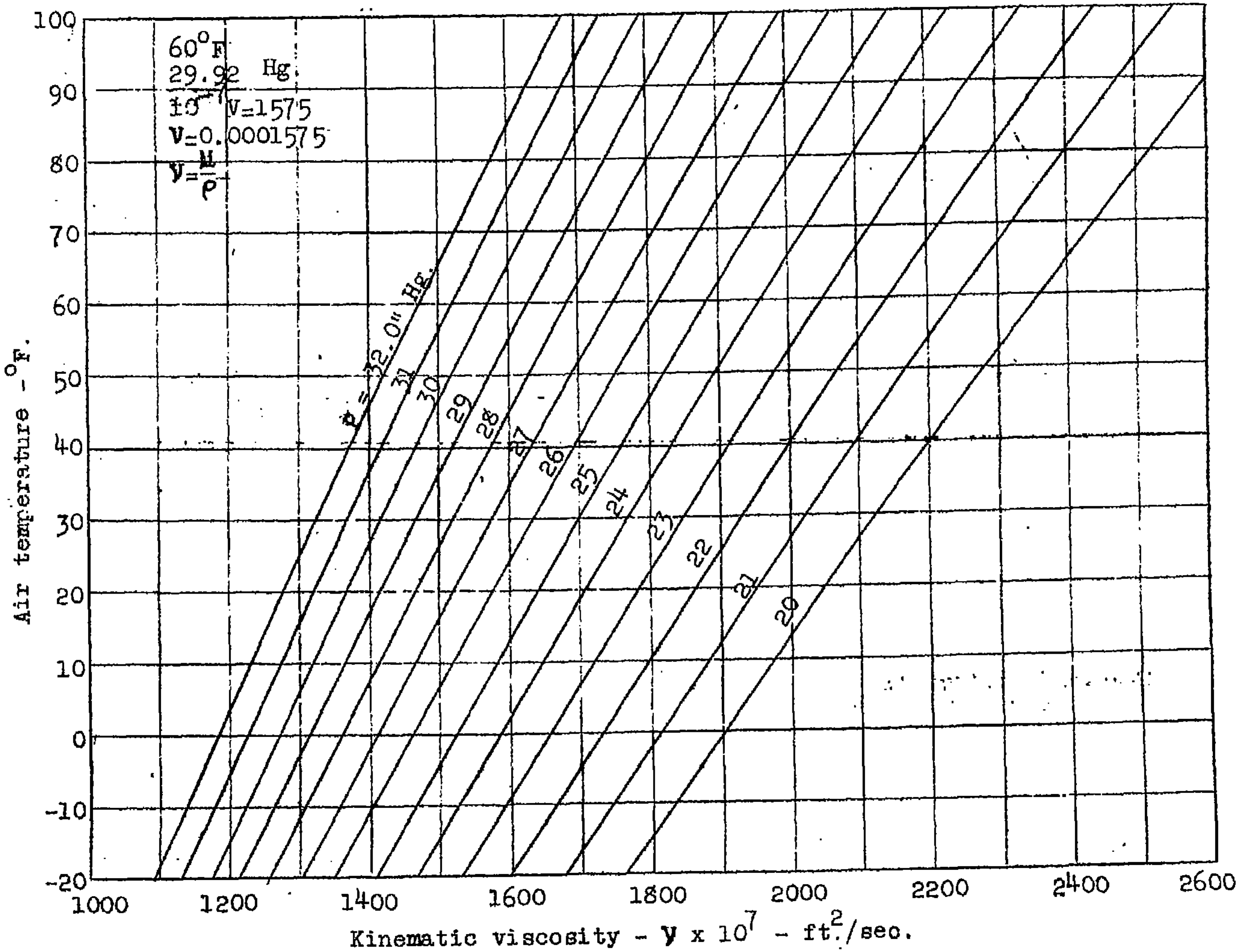
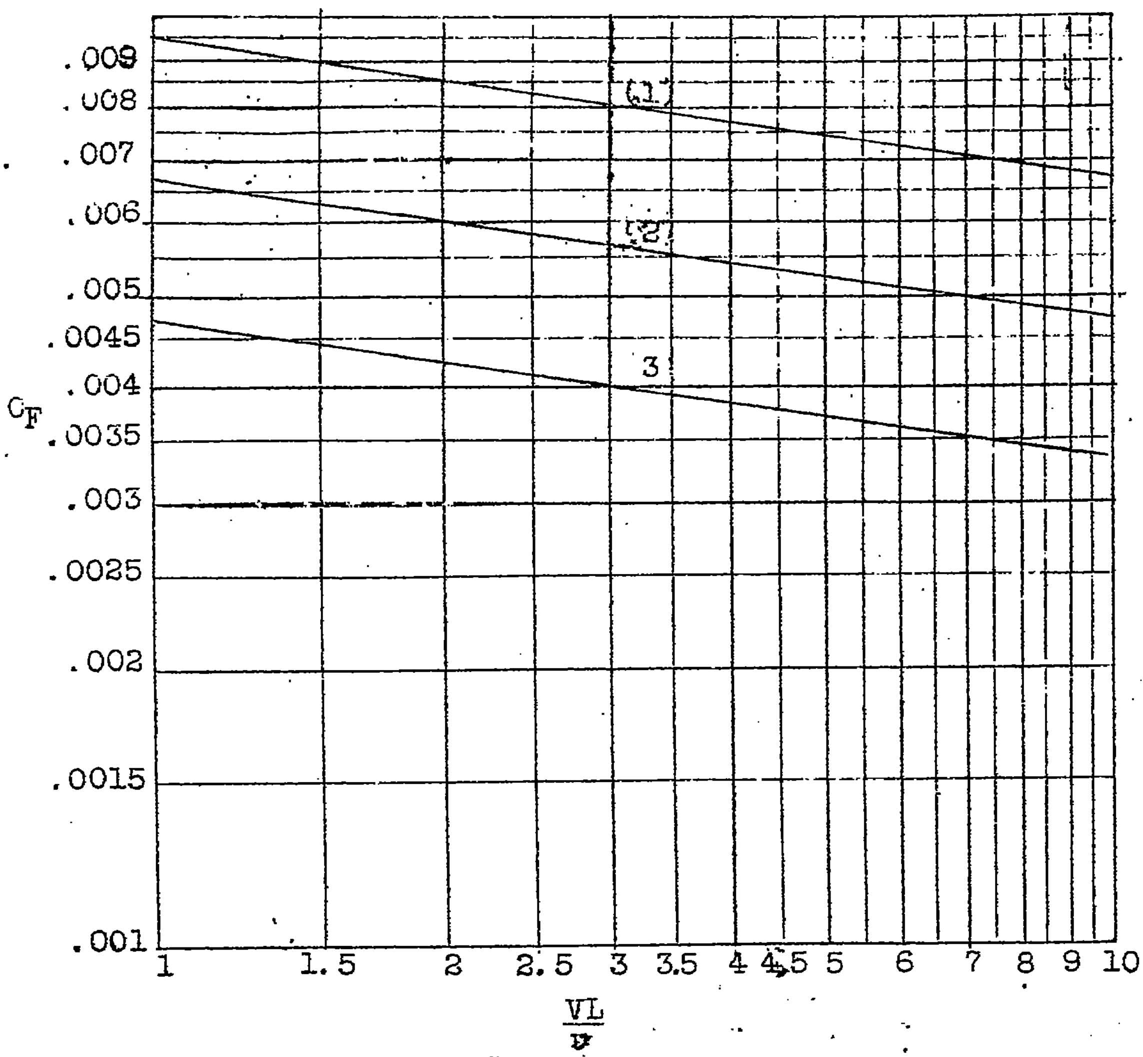


Fig. 1. Kinematic viscosity of air.



1 – $\frac{VL}{\nu}$	from	10,000	to	100,000
2 – "	"	100,000	"	1,000,000
3 – "	"	1,000,000	"	10,000,000

Fig. 2.